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[10191/2235]

## SEMICONDUCTOR ARRANGEMENT AND METHOD OF MANUFACTURE

[Background Information] FIELD OF THE INVENTION

The present invention [starts out from] relates to a semiconductor arrangement and a method for manufacturing the semiconductor arrangement [according to the species defined in the independent claims].

## BACKGROUND OF THE INVENTION

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German Patent [Application] <u>document</u> No. P 4320780.4 describes a semiconductor diode having a first layer made of two partial layers, and a second layer[, where the second layer] <u>which</u> is situated on the first partial layer.

15 [Summary of the Invention] <u>SUMMARY OF THE INVENTION</u>

[In contrast, the] <u>The</u> present invention's semiconductor arrangement and method for manufacturing the semiconductor arrangement[, which include the characterizing features of the independent claims, have] <u>has</u> the advantage of providing diodes having an increased maximum permissible power and less forward voltage[,] <u>for a given</u> [a constant] chip surface, in a manner suitable for large-scale mass production, without a large amount of additional engineering expense. This is particularly advantageous[,] when a maximum preselected chip surface area should not be exceeded in order to save chip surface, and when the size of the contact socket used to contact the semiconductor arrangement should not exceed a certain magnitude, in order to avoid paying for an increased current-carrying capacity of diodes particularly used in a

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MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

2motor-vehicle rectifier system, with an increased volume of the entire rectifier system. [Therefore, the] The present invention [shows how] facilitates, given a constant surface area of the silicon chip, the allowable current load [can] to be increased and the thermal loading of the silicon chip [can] to be reduced in a manner [whose technology] that can be realized relatively simply. In so doing, a reduction in the forward voltage is simultaneously achieved. The effect of additional saw grooves [proves to be] is particularly advantageous, because later, when the socket and lead wire are soldered to the diode chip, the grooves lead to a better, bubble-free soldering procedure (capillary effect), and the grooves filled with solder result in additional, more effective cooling of the chip, which extends into the depth of the silicon body and therefore thermally couples the chip to the heat sink in a more [intensive] effective manner.

[Additional advantages result from the further refinements specified in the dependent claims, as well as from improvements to the semiconductor arrangement and method indicated in the independent claims.]

[Brief Description of the Drawing] <u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

[Exemplary embodiments of the present invention are shown in the drawings and explained in detail in the following description.

30 The figures show:]

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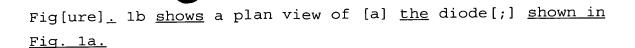
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Fig[ure]. 1a shows a cross-sectional side view of a diode[;] in accordance with the present invention.



Fig[ure]. 2 shows a semiconductor wafer used as the starting material in a method for producing the semiconductor arrangement in accordance with the present invention. [step; and]

Fig[ures]. 3 [and 4] shows the semiconductor wafer in a further method step[s] for producing the semiconductor arrangement in accordance with the present invention.

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Fig. 4 shows the semiconductor wafer in yet another method step for producing the semiconductor arrangement in accordance with the present invention.

[Description of the Exemplary Embodiments] <u>DETAIL DESCRIPTION</u>

Figure 1a shows a cross-sectional side view of a semiconductor chip 7, which is in the form of a diode. Chip 7 has a first semiconductor layer [(2, 3, 4),] which is made of a first partial layer 2, a second partial layer 3, and a third partial layer 4. The doping of n-doped partial layer 2 is on the order of 1018 cm-3. Partial layer 3 is n-doped to a concentration of approximately 1014 cm-3, and partial layer 4 is doped to an concentration of approximately  $10^{20}\ {\rm cm}^{-3}$ . Two trenches 10 are introduced into partial layer 2, which trenches extend into partial layer 3. These trenches 10 are situated in inner region 13 of chip 7. Edge regions 12 of the chip have a bevel 11, which extends into partial layer 3 as do trenches 10. Deposited onto first partial layer 2, both into trenches 10 and in bevel 11, is a second layer 20, whose regions in trenches 10 and bevels 11 are designated as continuation regions 23 and further continuation regions 24 of second layer 20, respectively. Second layer 20 is p-doped and has a doping on the order of 10<sup>20</sup> cm<sup>-3</sup>. The wafer topside, which is covered by layer 20, and the wafer bottom side, which is formed by layer 4, are provided with metallic coatings 22 and 21, respectively. Figure 1b shows a plan view of the [same component] chip 7 shown in Figure 1a. The top of chip 7 is covered by metallic coating 22. As a result of the trenches 10 that are introduced, this metallic coating 22 has a pattern characterized by corresponding depressions.

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The p-n junction region of the diode is formed by p-doped layer 20 and n-doped layers 2 and 3 of Figure 1a. As a result of the trenches 10 that are introduced, continuation regions 23 in interior 13 of chip 7 form a p-n junction with second partial layer 3. These regions lead to a reduction in the forward voltage of the diode, with metallic coating 22 being used as the anode and metallic coating 21 being used as the cathode. The four grooves in the interior of chip 7 (cf. Figure 1b) allow the electrical load to be increased by over 12% in comparison with an identically constructed diode not having grooves in the interior. In other words, a diode that can withstand, for example, a 65 A load may be converted to a diode having a maximum load of 75 A. An 80 A diode becomes a 90 A diode. The forward voltage may be reduced by approximately 60 mV (measured at a 100 A load). The four additional grooves or trenches in the interior of chip 7 also result in the chip being soldered more effectively and free of bubbles, i.e. the socket and lead wire are attached to the diode chip in an improved manner. In addition, the grooves filled with solder during this soldering procedure (not shown in the figure) ensure that the chip cools in an improved manner, since the solder in the grooves, which then completely fills the grooves, thermally couples the chip in an intensive manner, to a metal base used as a heat sink.

Figure 1b shows [represents the special case] an exemplary embodiment of a [square] chip 7, i.e., a square chip. However, not only are squares possible, but also other surfaces that are defined by straight edges (e.g. a hexagon or an octagon) and have additional, corresponding[,] internal grooves parallel to the edges.

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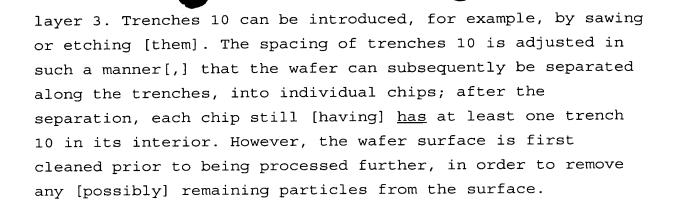
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Figure 2 shows a semiconductor wafer having a first partial layer 2, a second partial layer 3, and a third partial layer 4, which wafer is used in producing the semiconductor arrangement of the present invention. All three partial layers are n-doped. The starting point for manufacturing this sequence of layers is a weakly n-doped wafer, whose dopant concentration corresponds to the dopant concentration of partial layer 3. N-dopant, e.g. phosphorus, is then introduced onto and diffused into the topside and bottom side, using film diffusion. A layer, whose dopant concentration corresponds to partial layer 2, is consequently formed on the topside, and a layer, whose dopant concentration corresponds to partial layer 4, is formed on the bottom side. In this context, the dopant concentration of the layers is determined by the dopant concentration of the films.

The manufacture of such a layer sequence is already known from German Patent [Application] document No. P 4320780.4. As an alternative, this sequence of layers can also be manufactured using neutral films, as is described in the German patent application [having the number] No. 19857243.3.

Figure 3 shows a further step of the manufacturing method <u>for</u> <u>producing the semiconductor arrangement</u> according to the present invention. In this context, trenches 10 are introduced into the semiconductor wafer, which subdivide partial layer 2 into subsections, trenches 10 extending through to partial



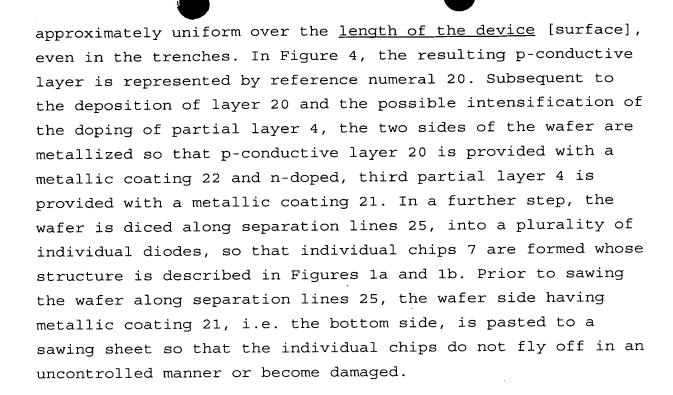
In comparison with the device and method described in German 10 Patent [Application] document P 4320780.4, the spacing of the saw lines is halved during the sawing-in procedure (in order to obtain two additional grooves per chip) or reduced to one third (in order to obtain four additional grooves per chip). In [this] the present case, the spacing of the grooves is 15 typically 1-3 mm. No additional method step is necessary here, since, as is known from German Patent document P 4320780.4, the sawing-in procedure is executed to lay out the chip edge, anyway. One must only set the line spacing to be somewhat smaller during the sawing-in procedure. This does not 20 considerably change the processing time of this sawing step, since the wafer handling, the alignment, and the cleaning with deionized water done in the automatic sawing device after the sawing-in procedure, are carried out anyway.

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After the introduction of trenches 10, a p-dopant such as Boron is introduced into the topside. At the same time, the dopant concentration of bottom layer 4 [can] may be increased if so desired [this appears to be advantageous]. P-dopant is introduced again, using film diffusion. In this diffusion step, possible defects present in the silicon monocrystal in the immediate vicinity of trenches 10 are repaired. The p-diffusion converts the top layer of the silicon wafer into a p-conductive region. The thickness of this p-layer is



The width of the saw lines during the sawing-in procedure is approximately 40 to 150  $\mu m$ , and the lengths of the chip edges are in the range of approximately 5 mm. The area of the additional saw grooves in the interior of the individual chips only makes up a few percent of the chip surface. Of course, the method of the present invention can also be used to manufacture diodes doped in an opposite manner, i.e. diodes where a p-doped wafer is used as a starting point, in place of an n-doped wafer.